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GEOLOGIC AND PETROGRAPHIC NOTES ON THE REGION ABOUT CAICARA, VENEZUELA[1]

T. A. BENDRAT
Turners Falls, Massachusetts

In the winter of 1908–9, the writer carried on some independent studies along petrographic and geologic lines, in the interior of Venezuela, choosing for his field of investigation the region immediately west of the so-called "El Caura District," at the famous bend of the Orinoco, and mapping an area of 1,400 sq. km., which was hitherto very little known. While the general results of this survey have been summed up elsewhere,[2] it is on the main geologic and petrographic features of the region that the writer wishes to offer the following observations.

GEOLOGIC STRUCTURE

I. THE BED ROCK

The bed rock consists of a series of granites and gneisses which, wherever they come to the surface, show a predominance of the gneiss over the granite. These granites and gneisses rise from the bottom of the Orinoco channel; constitute the base of many of the islands; are exposed in the banks of the river, particularly in the dry season; and back from the river form the bulk of the "Cerros." These cerros are hills and small mountains which rise above the plain of the sabana. In general they increase in height in proportion to increasing distance from the Orinoco, and may be regarded as outliers of the Guiana mountain system lying to the south. These cerros are probably to be considered as portions of the great series of granites and gneisses which have most effectively resisted disintegration, partly because a skeleton of numerous veins and dikes cutting each other in all possible directions traverses them.

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[1] The writer desires to express at this place his high obligations to Professor B. K. Emerson of Amherst College who was kind enough to have the petrographic microscopes of Smith College, Northampton, Mass., placed as his disposal.

[2] Petermann's *Geogr. Mitteilungen* (1910), Bd. 56, v; *Geographen Kalender* (1909), 221.

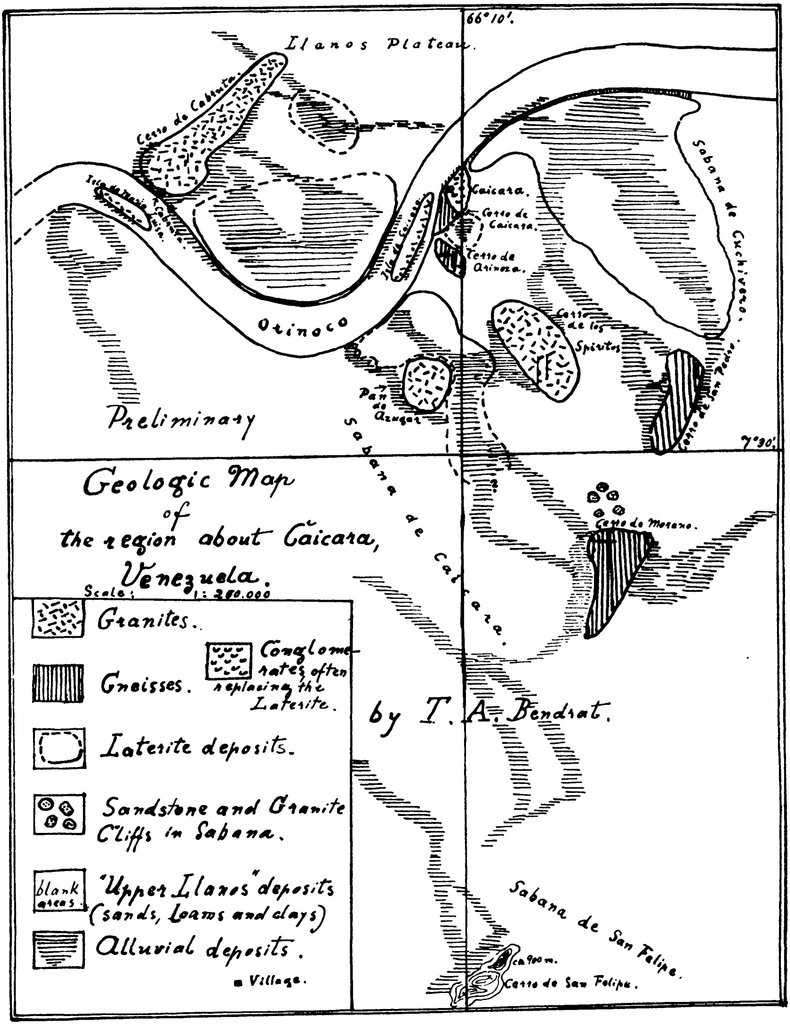
An extended survey of the shores of Isla de Caicara, opposite the village of Caicara, showed that the bed rock of this island is a medium-grained granite of comparatively firm texture, which is drab colored in fresh breaks, but which weathers to a purplish tint. This rock shows cleavage planes extending north and south, and east and west.

The cliffs exposed on the Caicara side of the stream by the falling of the Orinoco during the dry season consist of medium to fine-grained gneiss, whose laminations run either N.N.E.–S.S.W., or E.N.E.–W.S.W. Quartz veins, varying in thickness from three to five inches, cut the gneiss in a general N.W.–S.E. direction. It was on the surface of one of these rocks, about 1 km. north of Caicara, that the writer discovered what, considering the latitude, would seem a very curious phenomenon. This consisted of three grooves, about five inches long and one-eighth inch deep, which run perfectly straight, one N. 80° E., and the two other S. 80° E. They show a striking resemblance to glacial striae, but this does not exclude the possibility that they may have been produced by man, as in close proximity a series of the so-called "petroglyphics" was found, the grooves of which, however, were considerably deeper and wider. The surfaces of the rocks on which the grooves were observed were considerably smoothed, as were the rocks of the banks of the Orinoco, but this might be due to the effects of the currents.

The distribution of the granite and the gneiss in the hills and ridges north of Cabruta and south and southeast of Caicara also plainly reveals the prevalence of the gneiss over the granite, for, with the exception of Cerro de Cabruta, north of the Orinoco, and Cerro de los Spiritos, the lower portion of Cerro de Arinoza, and possibly the whole of Pan de Azugar, all the cerros consist of gneiss (see map, Fig. 1).

The Cerro de Cabruta, rising abruptly at its southwestern terminus from the waters of the Orinoco to a height of about 290 meters above sea-level, trends, for a distance of about 12 km., in a N.E. direction, and gradually falls off toward the llano plateau.

The cerro is entirely made up of a coarse-grained feldspathic granite, which weathers to a dull reddish purple, and in fresh cuts has a



For geographic map see "Petermanns Mitteilungen" 1910, plate 46.

FIG. 1

yellowish-white color. The yellow predominates over the white. Toward the top, the granite becomes more and more quartzose, while at the same time the quartz veins become more and more frequent. Some of these quartz veins strike parallel to the general cleavage planes, that is N. and S., while others run E. and W., and W.N.W. and E.S.E. The disintegration of the granite by means of exfoliation was most strikingly exhibited on the top. At one place a dike of gray to bluish-white quartz cut the granite in a direction N.N.W. and S.S.E., which most probably determined the initial direction of the southwestern spur of the cerro. Along the line of contact, the granite seems to have become changed locally into gneiss with lamination in a direction N.N.W. and S.S.E. This was, however, the only instance of a gneissic phase observed in the bulk of the granite.

Of the series of cerros on the southeast side of the Orinoco, the Cerro de Caicara comes first and lies immediately south of the village of Caicara. It rises to a height of 127 meters above sea-level and extends about 2 km. to the south, along the bank of the stream. It consists entirely of a more or less fine-grained gneiss of light color, but on weathering becomes a dark purple. At different levels the gneiss is highly charged with various grades of iron oxide, which exhibit beautiful shades of color, ranging from tan through ochre yellow to a dark bloody red. The direction of lamination is, in most cases, parallel to the general strike of the rocks.

About 3 km. south of Caicara lies the Cerro de Arinoza, which attains a height of 146 meters, while its foot is 71 meters above sea-level. Only the lowest levels of this hill consist of a close-grained quartzose granite such as was encountered in the Cerro de Cabruta. The structure of this granite is in places pegmatitic and the cleavage planes run N. and S., and E. and W., as do quartz and pegmatite veins. Higher up in the slope, however, the granite yields to a medium-grained gneiss, the laminations of which run S. 20° E. and dip at an angle of 27° to the northeast.

The Cerro de los Spiritos is situated about 5 km. east of Pan de Azugar, and nearly 8 km. S.S.E. of the village of Caicara. About 200 feet high, it trends in a general N.W.–S.E. direction for over 5 km. With a possible exception of Pan de Azugar, as indicated above, it is the only cerro southeast of the Orinoco within the scope of the region under discussion which is entirely composed of granite. It is of the coarse-grained feldspathic type and exhibits joints which run pronouncedly N. and S., E. and W., and N.W.–S.E., and in no other direction. The backbone of the hill is a quartz dike from 3 to 5 feet wide, which runs along the southwestern flank of the hill in a N.W.–S.E. direction. Assays made of samples from this dike reveal traces of gold. Other quartz dikes run parallel to this one as well as at right angles to it, while near the top a dike of pinkish felsite about 2 feet thick and running E.–W. stands out prominently from the surrounding coarse-grained granite, which assumes a rather hornblendic aspect in the upper levels. The flanks of the cerro, where slopes are gentle, and only occasionally steep, are dissected by gullies and ravines running parallel to the main quartz dikes in the main.

About 26 km. S.S.E. of Caicara the Cerro de Morano rises above the plain of the sabana in two distinct knobs which have heights of 375 and 396 meters respectively above sea-level. Its topographic outlines seem to be determined by two main quartz dikes, the more prominent one running N. and S., constituting the backbone of the cerro. Approaching the cerro from the north, one encounters knobs and cliffs emerging from the sabana, which consist of purplish weathering, coarse-grained feldspathic granite, occasionally highly charged with iron oxides, and at places overlain by limited (in size) "banks" of ferruginous coarse-grained sandstone. But the bulk of the cerro itself is made up of hornblende gneiss, which ranges from fine to coarse grained. The average direction of lamination is N. and S., and N.W. and S.E.

2. THE SABANA DEPOSITS

In dealing with the deposits of the sabana, above which rise the isolated cerros just described, one must distinguish between the so-called "Laterite" deposit and what Dr. S. Passarge terms "Upper Llanos" deposits.

1. *The "Laterite" deposit.*—This deposit is a concentration of iron oxide in a series of more or less fine and soft clays of a light gray color. Deposits of this class have been found by Dr. S. Passarge along the banks of the Cuchivero as well as the Caura,

and by the writer overlying the gneisses on the banks of the Orinoco. As long as the deposit is under water or is still charged with water after the streams have fallen during the dry season, it is very pliable; but as soon as it becomes dehydrated, it turns extremely hard and takes on the aspect of a clay ironstone. It has been called "Laterite," and likened to the German "Zellinger Brauneisenstein." The only true laterite portions form the upper part of the clayey mass or are segregated from this. The clays are in many places marbled by a more or less intense red. The deposit directly and unconformably overlies the gneissic or granitic bed rock. The deposit is not continuous and is frequently replaced by a conglomerate, cemented by iron oxide (see Fig. 2). It occurs inland as well as along the Orinoco.

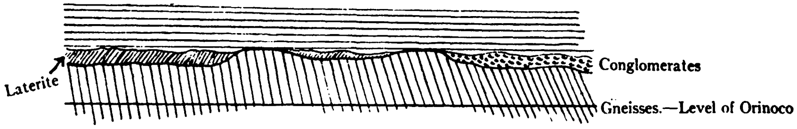


FIG. 2

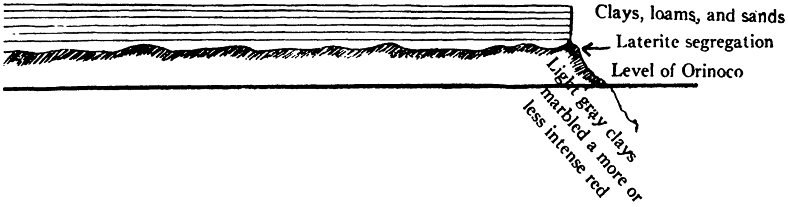


FIG. 3

2. *The Upper Llanos deposits.*—The Upper Llanos deposits which, as a rule, unconformably overlie the "laterite," wherever they have not been removed by erosion, may be said to consist of the following three members: (1) A whitish or yellowish clay which exhibits yellowish-brown cell structure, rich in iron; (2) loams of various nature; (3) sands of different fineness and color.

Their interrelation changes with the locality and so do their respective horizons. They constitute the upper portions of the islands, as well as the upper terraces at an elevation of 50 feet, approximately, above the average level of the lower terraces, and finally, the sabana itself. They lodge between the rocks of the granites and gneisses, wherever these come to the surface, filling in interspaces. The loam becomes very pliable and soft during the rainy season, so much so as to allow mud turtles to plow furrows from half a foot to a foot deep in it. Local torrents sometimes carve channels down to the underlying laterite. The walls of these channels become extremely indurated during the dry season, rendering traveling across the sabana under such conditions laborious, especially where there are no roads or paths available.

PETROGRAPHY OF THE GRANITES AND GNEISSES THAT CONSTITUTE THE CERROS IN THE SABANA ABOUT CAICARA

I. THE GRANITES

The granites of the region under consideration comprise those of the Cerro de Cabruta, the Cerro de los Spiritos, and those at the base of the Cerro de Arinoza. A detailed microscopical study of specimens taken from different levels shows that in all three cerros the type of granite is essentially the same. This statement, however, has to be modified in so far that, at one end of this elliptic area, the granite is decidedly leukocratic while at the other it is melanocratic. While the Cerro de Cabruta consists of a more or less pronounced quartzose granite in its upper levels and its top, the Cerro de los Spiritos reveals a decided predominance of hornblende in the granite of its top.

Though described here in general terms as granite, this rock is more correctly designated as quartz monzonite porphyry. Its ground mass is made up of more or less angular or subangular crystals of quartz and feldspar through which the leading minerals are sprinkled as phenocrysts. These phenocrysts are quartz, which sometimes predominates over the feldspars, occasional orthoclase associated with, or replaced by, microcline, the soda-lime and lime-soda feldspars albite and labradorite, and finally biotite, associated with or entirely replaced by hornblende.

Quite a number of quartz and feldspar phenocrysts show enlargement by secondary growth as revealed by zonal extinction or by a more or less faint ring of dark material, apparently representing a coating of the original grain.

The frequent occurrence of a micro-pegmatitic texture suggests conditions in the original magma that favored a simultaneous crystallization of the quartz and feldspar.

Of the feldspathic minerals those of the soda-lime group apparently prevail over the orthoclase (not so much over the microcline), and among them labradorite is the one most frequently found.

The biotite occurs in lath-shaped crystals and in shreds and flakes, the amphibole mostly with prismatic outlines, and only occasionally in cross-sections. It was in such a cross-section that an intergrowth of biotite and amphibole was observed, the former penetrating the latter, clearly demonstrating their contemporaneous development. Apatite and titanite occur as inclusions in the biotite, while the amphibole contains apatite and magnetite. Microlites of biotite and apatite needles have been observed in feldspar, while quartz carries magnetite, apatite, and occasionally zircon. In cavities within the quartz liquid inclusions are sometimes present. Titanite is also found free in wedge-shaped crystals, and considerable garnet, in more or less complete crystals, occurs. Secondary minerals are calcite, which might have been derived from some of the feldspars, and chlorite, which apparently has come from the biotite.

Wavy extinction in quartz and feldspar; bending, breaking, and slicing of feldspar and biotite; granulation of feldspar and occasionally of quartz; and the complete crushing of titanite crystals strongly suggest dynamic stress and shearing.

The occurrence of looped grains of orthoclase, and the more or less advanced decomposition and the decoloration of a considerable percentage of the biotite indicate katamorphic action, most probably by descending waters, while the secondary growth of minerals, involving zonal structure, and the formation of veinlets, where crystals were broken, tell rather of the anamorphic activity of ascending solutions.

2. THE GNEISSES

The gneisses of the cerros in the sabana of Caicara comprise those of the Cerro de Caicara, Cerro de Arinoza, with the exception of its base, and those of the Cerro de Morano. A microscopic analysis of thin sections of samples taken from all levels of these cerros, and a comparison of their composition, texture, and fabric, tend to lend much weight to the assumption that the gneiss throughout belongs to one and the same unit, as it was one and the same type of rock we had to deal with in the granites. This statement is, however, not intended to exclude the possibility of local phases representing gradation and variation.

Like the granite, the gneiss is porphyritic. In a ground-mass commonly of angular or subangular grains of quartz, with rather fringed and dentated outlines, and of feldspars, especially microcline and plagioclase, which usually are arranged with their longer diameters parallel or slightly inclined to the plane of rock-cleavage, are imbedded phenocrysts of pegmatite, microcline, albite, labradorite, and biotite. All of these minerals, with the exception of the biotite, are more or less allotriomorphic. Microcline seems to take the place of orthoclase to a great extent, wherever the latter is not intergrown with quartz, and we might say that the predominance of microcline and pegmatite constitutes one of the main features of this gneiss. Another feature is the frequent occurrence of crossed lamellae in the plagioclases and a marked tendency to form rather broad lamellae.

Of the feldspar and quartz the former is in excess. Among the ferro-magnesian minerals, biotite, in phenocrysts of lath-shaped form and in flakes, seems to be almost the only representative. Hornblende is very seldom encountered, though in one instance it was found intergrown with biotite.

Of accessory minerals an occasional crystal of pyroxene is encountered, while magnetite and hematite are more frequently met with. Garnets are not uncommon and wherever they occur they are idiomorphic. Chlorite is present most probably as a decomposition product from biotite and hornblende.

As regards inclusions in the different minerals, magnetite occurs in feldspars, arranged more or less parallel to the plane of parting, and in quartz where it occurs as a cloudy matter and in dendrites. Of other inclusions may be mentioned zircon, apatite, titanite, and tourmaline (?) in quartz, and very fine glassy particles in the plagioclases.

The gneisses, even more than the granites, exhibit overwhelming evidence of metamorphism, during, as well as since, their formation. Among the evidences of stress and shearing, may be mentioned: The wavy extinction in quartz and feldspar grains; the bending of biotite; the differential bending and anastomosing of the lamellae of feldspars; cracks and fractures parallel or normal to the plane of parting in biotite; the slicing of crystals of pegmatite and microcline; the breaking of crystals of feldspar and biotite and displacement of the broken parts by miniature faulting; a granulation zone about grains of pegmatite.

A gneissoid texture is given to the rock by the more or less parallel arrangement of the longer axes of the minerals to the plane of schistosity of the rock.

The dissolving agency of descending waters is shown by the schiller structure of some plagioclases, the cloudy appearance of other feldspars, and the decomposition of some of the magnetite, biotite, and hornblende. The anamorphic agency of ascending waters is indicated by secondary growth of quartz, plagioclase, and biotite; by the cementing of cracks and fissures, and by the formation of veinlets by segregation from the same mineral or by infiltration from some other source.

3. THE VEINS AND DIKES IN THE GRANITES AND GNEISSES

The writer profoundly regrets that he did not have time to examine more closely the veins and dikes of the cerros about Caicara, as a more detailed and special study of these veins and dikes most probably would have brought out different sets, as indicated by uniformity of strike and dip and of composition, and might have shown something in relation to the nature and the succession of the dynamic movements which the gneisses and the granites, individually or together, have undergone.

While the writer is far from attaching any special significance to it and deducing any particular law of succession from it, because of the limited material on hand, it is nevertheless a peculiar fact that all of the more prominent quartz veins and dikes encountered have a strike magnetic N.–S., while all the pegmatite veins and dikes strike E.–W. Near the summit of Cerro de Morano a vein of fine-grained amphibolitic gneiss, varying in thickness from two to three feet, strikes N.–S. A few feet below the top of Cerro de los Spiritos a felsite vein about one foot thick extends E.–W. and stands two feet above the surrounding coarse-grained granite, so that from a distance it has the appearance of the remnant of a brick wall. A microscopic investigation showed that its main constituents are quartz and plagioclase in nearly equal proportions, while some dark-brown and yellow biotite occurs as an accessory mineral. A microscopical examination of the N.–S. quartz veins shows that they are made up of very small grains of quartz with dentated margins in most cases and most intricately interlocked; of bronze-brown to dark-green amphibole in irregular patches; occasional tourmaline in radiate aggregates; some garnets, and some magnetite.

In concluding, the writer wishes to remark that it would be of great interest to ascertain the geologic and petrographic nature of other outliers in those waste plains that approach the Orinoco from the S. and from the E., as well as the character of the rocks that make up the bulk of the Guiana mountain system, in order to bring out facts that would bear on the relations of those cerros to this, most probably, Archaean center.